Comparative Analysis of Uncertainties in Urban Surface Runoff Modelling

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Analyse comparative des incertitudes sur la modélisation du ruissellement urbain

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Keyword : urban runoff modelling; uncertainties; extreme event statistics; combined sewer overflow; flooding

In analysis and design of urban drainage systems, an important tool for the consulting engineer is commercial urban drainage models such as MOUSE, InfoWorks, SWMM, etc. However, if results from these models are used in decision-making, it is all-important that the results are valid and correspond the reality. Emphasizing this may seem as a triviality, but never the less, the majority of model setups are employed with only the most important site specific input data and mostly without calibration, indeed causing uncertain model predictions. Wrong decisions, based on a defective model predictions, can in the worst case cause unnecessary flooding or combined sewer overflows, or on the other hand result in over-dimensioned - and with that excessively expensive – drainage systems with poor self-cleansing. Therefore it is crucial to clarify where the main uncertainties in urban drainage models are located in order either to reduce the uncertainties or to take precautions in the decisions based on models results.

In order to manage or reduce model errors, it is advantageous to separate the uncertainties of a model into different types (or natures), as it is done by several authors, e.g. Walker et al. (2003). In this paper a pentad of uncertainties is applied, with the following components: input data uncertainties, calculation parameter uncertainties, physical structure uncertainties, model methodology uncertainties and observation data (or calibration data) uncertainties.

The object of this paper is to investigate a specific part of an urban drainage model, namely the surface runoff, as it is the author’s conviction that this part of an urban drainage model is encumbered with many and relatively large errors, as the mathematical description of surface runoff contain a rather large number of parameters, at least when more complex models are applied. Traditionally it is assumed that complex models, which contain many parameters, have a larger parameter uncertainty whereas the model methodology uncertainties are smaller due to the more detailed mathematical description. Contrary a simpler model contain fewer parameters, and thus less parameter uncertainty but larger model methodology uncertainty. So the smallest overall uncertainty is found somewhere in between a very simple and a very complex model, however depending on the observation data available.

Regarding uncertainties and model errors, it is preferable to divide the surface runoff into hydrological surface processes and hydrodynamic surface flow (or routing) processes and, as the first mentioned are causing to zero-order errors (i.e. volume errors), and the latter is causing to first and second order errors (i.e. errors in the temporal flow variations). The paper primarily investigates the model methodology uncertainty and calculation parameter uncertainties. Both simple and complex hydrological approaches are compared as well as three different surface runoff flow models with different complexity are compared, a time-area model, a kinematic wave model, and a linear reservoir model.

In the paper it is shown a well calibrated time-area model (simple model) can be used to setup the other two models, and how it is practically difficult to get a valid result of a more complex model, if a simple model is not setup first. Finally it is investigated in what way the choice of surface runoff model is decisive for extreme event statistics, i.e. for number and volume of surcharges from combined sewer overflows to local recipients and for flooding of critical areas e.g. basements or ground level.

This study is carried out on the basis of the Frejlev catchment where several investigations already have been completed, e.g. Schaarup-Jensen et al. (1998), Schaarup-Jensen et al. (2005), Schaarup-Jensen & Rasmussen (2004), Thorndahl et al. (2005). Frejlev is a small town of approx. 2000 inhabitants, 7 km southwest of Aalborg, Denmark. The partly combined and partly separated drainage system, is equipped with two high resolution electromagnetic flow-meters (Schaarup-Jensen et al. 1998), which constant measures the runoff, in both dry and wet weather, from the catchment of approx. 80 hectares. In addition to this two automatic tipping-bucket rain gauges managed by the Danish Waste Water Control Committee and operated by the Danish Meteorological Institute, are located within the catchment.

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